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ORIGINAL ARTICLE

Physicians' characteristics associated with repeat use of computed tomography and magnetic resonance imaging

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Background/purpose: The use and cost of computed tomography (CT) and magnetic resonance imaging (MRI) are both very high. The purpose of this study was to evaluate the relation between physicians' characteristics and the CT and MRI repeated within 90 days, using a nationwide population-based data set from Taiwan's National Health Insurance system.
Methods: All physicians who ordered CT and MRI examinations in 2004–2005 were identified. We analyzed the total number of CT and MRI scans, the number of repeat scans, and the repeat scan rate, according to physician characteristics (specialty, age, sex, and type of practice hospital). A multivariate logistic regression analysis was performed to explore the adjusted relationship between physician characteristics and their rate of ordering repeat CT and MRI.
Results: A total of 16,307 physicians were responsible for a total of 2,152,292 CT and MRI scans during 2004–2005 in Taiwan. The repeat scans accounted for 21.5% of the total scans. Male physicians and physicians aged 41–50 years ordered more repeat scans. Internal medicine physicians ordered 44.3% of all scans and 50.6% of all repeat scans. Surgeons ordered 40.4% of the total scans and 38.5% of repeat scans. Internal medicine physicians were the most frequent users of CT/MRI scans. Family doctors, obstetricians/gynecologists, and pediatricians ranked last among the specialists. Physicians who practiced in medical centers ordered the most CT/MRI scans.

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Conclusion: Our study shows that repeat use of CT and MRI scans is related to physicians' characteristics. We recommend that different monitoring standards should be set for CT and MRI repeat use by physicians of different specialties and in hospitals of different accreditation levels.

Introduction

Use of high-cost imaging modalities, such as computed tomography (CT) and magnetic resonance imaging (MRI), has increased rapidly in recent years. Imaging is one of the most rapidly growing sectors of the health care industry.[1,2] Bhagavan and Sunshine[3] reported that the use of CT and MRI increased by 7–16% per year between 1998 and 2001 in the USA. In a private insurance coverage data set in California, Mitchell[2] showed that CT and MRI increased by 50% between 2000 and 2004. In Taiwan, the government initiated its National Health Insurance (NHI) program in 1995. It is a compulsory, monopolized, and comprehensive health insurance program. Taiwan NHI covers nearly all types of medical expenditure, including CT and MRI. There is either no co-payment, or a very low co-payment for a patient to receive CT or MRI examinations. Therefore, the use and expenditure of both CT and MRI are very high in Taiwan.[4]

There are a lot of reasons for the high use of both CT and MRI. Kung et al reported that health care supply side factors were the most important factors affecting increased CT or MRI use in Taiwan.[4] Tsai et al[5] also reported that an increase in the number of physicians increased the medical expense. Based on the information from one medical center in the USA, Lee et al[1] reported that repeated examinations account for one-third of high-cost radiological examinations. The reason for repeat scans may be doctors' behavior, including self-referral from the radiologists.[6] However, other studies on the behavior of radiologists versus other physicians, including self-referral, have shown different results, suggesting that the overuse of high-cost imaging examinations was because of physicians', not radiologists', behavior.[1,7,8] From the above studies, we hypothesized that physicians' characteristics affect the repeated use of both CT and MRI, and therefore affect the total medical expense. To our knowledge, there are no reports that have analyzed repeated use of such imagining technologies using a national database to compare doctors of different specialties.

The rate of Taiwan NHI coverage was approximately 98% of the population in 2005.[9] The NHI database provides a unique opportunity to study the behavior of all types of physicians and the use of high-cost imaging modalities. In view of the increasing cost of health care incurred by frequent use of expensive imaging modalities, the Bureau of NHI is compelled to restrict repeated CT and MRI within 90 days of a prior scan. The purpose of this study was to evaluate how physicians' characteristics are associated with use of CT and MRI repeated within 90 days, using the nationwide population-based data set from Taiwan's NHI. We also discuss how the government or insurance company sets restrictions for the repeated use of these image modalities.

Materials and methods

Database and data acquisition

This study used 2004–2005 data obtained from the National Health Research Institute. This database contains the medical benefit claims for inpatient, outpatient, and emergency department care for almost the entire 22.3 million citizens of Taiwan (~98% of the total population of Taiwan), and includes registries of contracted medical facilities, board certified physicians, and details of patient care orders. A de-identified data set (both patients and physicians providing data were de-identified) was extracted for 2004–2005. The study was approved by the National Health Research Institute and did not require institutional board approval or informed consent.

Study sample

All physicians who ordered CT and MRI examinations for inpatient, outpatient, and emergency services from 2004 to 2005 were identified from the database. Of these, CT/CT, CT/MRI, and MRI/MRI examinations performed within 90 days of each other for the same patient were selected. The reasons for choosing a 90-day period were to evaluate the monitoring of repeat CT or MRI scans within 90 days set by the NHI, and to exclude examinations performed for necessary annual screenings or a different illness.[1] The total number of CT and MRI scans, the number of repeat scans and the repeat scan rate per physician (number of CT and MRI scans repeated within 90 days ordered by each physician/number of total CT and MRI scans ordered by each physician $\times$ 100%) were calculated. The data were compared in terms of the physician's characteristics, including specialty, age, sex, and practice hospital level. Physicians' age was categorized into four age groups: <31 years, 31–40 years, 41–50 years, and ≥ 51 years. Physicians' specialties were categorized as internal medicine, surgery, obstetrics/gynecology pediatrics, family care, emergency room, nonspecialist medical doctors, and others. The accreditation levels of the physicians' hospitals (medical center, regional hospital, and community hospital) were also identified.

Statistical analysis

The SAS statistical package (version 9.2, SAS Institute, Cary, NC, USA) was used for analysis. The analysis unit was physicians, with physician characteristics (age, sex, specialty, and accreditation of the physicians' hospitals) as the key independent variables of interest. The key dependent variable was each physician's rate of use of CT and MRI

repeated within 90 days among inpatient, outpatient, and emergency services all across Taiwan's hospitals. Associations between the repeat scan rate and physicians' demographic characteristics were analyzed by one way analysis of variance. Multivariate logistic regression analysis was then performed to explore the adjusted relationship between physicians' characteristics and the repeated use of CT and MRI. Because the distribution of the repeat rate was not normal, the data were analyzed by logarithm transformation. A p value of 0.05 or less was considered statistically significant.

Results

There were 41,277 physicians in Taiwan during 2004–2005 and 39,367 physicians for whom there were detailed data sets available were included in the study. Of these, we selected a total of 16,307 physicians who were responsible for CT or MRI during these 2 years. They ordered a total of 2,152,292 CT/MRI examinations. Among these, 462,179 imaging examinations (21.5%) were repeated within a 90-day period (Table 1).

Physicians' age

Physicians who ordered CT/MRI scans were divided into four groups based on their age. We found that physicians aged 41–50 years used CT and MRI the most. For example, 5053 physicians who were 41–50 years of age ordered 890,378 CT/MRI scans, accounting for 41.4% of all scans. They also accounted for 42.7% of the repeat scans, which was the highest of the four age groups (Table 1). Each of the physicians ordered 39.0 ± 85.2 repeat CT/MRI scans, and the repeat scan rate per each physician (16.6 ± 14.6%) was also the highest in the four groups. The p value was 0.0009 for the four age groups (Table 2). The coefficient was 0.16 [95% confidence interval (CI): 0.10–0.22, $p < 0.0001$] (Table 3).

Physicians' sex

Male physicians ordered 93.6% of CT and MRI scans. The ratio of male to female physicians who ordered CT or MRI was 14,168:2139 (~6.6:1, Table 1). If we take into consideration the average scans ordered by each physician, male physicians ordered scans approximately 2.2 times (142.2/64.0) more often than female physicians. This was also true for the repeat CT/MRI scans (2.1 times, Table 2). Male physicians also had a significantly higher repeat scan rate (16.5 ± 16.1%) than female physicians (Table 2). The coefficient was 0.2 (95% CI: 0.14–0.26, $p < 0.0001$) (Table 3).

Physicians' specialty

Internal medicine physicians ordered 954,414 scans (44.3% of all scans), which was the most of all disciplines. Surgeons

Table 1 Use and repeated use of CT/MRI scans in relation to physician's demographic characteristics

	No. of physicians in Taiwan n = 39,367	No. of physicians ordering the examination n = 16,307	No. of CT and MRI scans $n1$ = 2,152,292		No. of repeated CT and MRI scans $n2$ = 462,179		χ^2 test for repeat scans
			$n1$	%	$n2$	%	
Age (y)							
<31	5557	1964	62,318	2.9	11,982	2.6	<0.0001
31–40	11,076	6822	845,158	39.3	177,110	38.3	
41–50	10,783	5053	890,378	41.4	197,195	42.7	
≥51	11,951	2468	354,438	16.7	75,892	16.4	
Sex							
Female	5071	2139	136,977	6.4	30,389	6.6	<0.0001
Male	34,296	14,168	2,015,315	93.6	431,790	93.4	
Specialty							
Internal medicine	8200	5236	954,414	44.3	233,742	50.6	<0.0001
Surgeon	9137	4826	869,971	40.4	177,743	38.5	
OBS/GYN	2464	872	29,959	1.4	4348	1.0	
Pediatrics	3083	1021	33,401	1.6	4819	1.0	
Emergency	316	283	102,406	4.8	13,710	3.0	
Family	2496	543	19,132	0.9	2804	0.7	
Others	3039	1138	55,462	2.6	9059	2.0	
Nonspecialist	10,632	2388	87,547	4.1	15,954	3.5	
Hospital accreditation							
Medical center	—	8183	974,247	45.3	242,335	52.4	<0.0001
Regional hospital	—	5839	906,428	42.1	184,703	40.0	
District hospital	—	2285	271,617	12.6	35,141	7.6	

CT = computed tomography; MRI = magnetic resonance imaging; OBS/GYN = obstetrics/gynecology.

Table 2 Analysis of the repeat scan rate per physician and physicians' characteristics

	No. of physicians $n = 16,307$	Number of CT and MRI/ physician		Number of repeated CT and MRI/ physician		Each physician's repeat scan rate		One way analysis of variance
		Mean	SD	Mean	SD	Mean	SD	
Age (y)								
<31	1964	31.7	84.4	6.1	20.7	16.0	22.5	0.0009
31–40	6822	123.9	213.6	26.0	55.8	16.5	16.1	
41–50	5053	176.2	292.0	39.0	85.2	16.6	14.6	
≥51	2468	143.6	293.1	30.8	89.3	15.1	15.5	
Sex								
Female	2139	64.0	151.5	14.2	42.5	14.5	18.7	<0.0001
Male	14,168	142.2	257.3	30.5	73.1	16.5	16.1	
Specialty								
Internal medicine	5236	182.2	269.3	44.6	91.1	19.8	13.9	<0.0001
Surgeon	4826	178.2	292.9	36.4	75.6	16.4	14.3	
OBS/GYN	872	34.4	76.8	5.0	18.9	9.0	13.4	
Pediatrics	1021	32.8	66.0	4.7	14.0	8.7	13.5	
Emergency	283	360.5	405.0	48.3	62.9	13.6	11.0	
Family	543	35.2	94.9	5.2	16.7	9.6	15.3	
Others	1138	48.7	140.7	8.0	21.8	16.5	22.2	
Nonspecialist	2388	41.2	115.5	7.6	28.3	15.4	22.2	
Hospital accreditation								
Medical center	8183	143.8	258.6	34.6	79.6	18.8	17.4	<0.0001
Regional hospital	5839	137.8	249.1	27.0	65.9	14.7	15.3	
District hospital	2285	74.9	186.9	9.3	26.3	10.6	14.4	

CT = computed tomography; MRI = magnetic resonance imaging; OBS/GYN = obstetrics/gynecology; SD = standard deviation.

ordered 869,971 (40.4%) scans. Both of these specialties were most likely to order two or more scans within 90 days of the initial scan, whereas obstetricians/gynecologists, pediatricians, and family physicians were least likely to do so (Table 1). Analysis of scans per physician showed that doctors in the emergency room ordered 360.53 ± 405.01 scans and 48.25 ± 62.9 repeat scans, which were the highest among all physicians. Doctors of internal medicine had the highest repeat scan rate per physician (19.8 ± 13.94%, Table 2). The coefficient was 1.16 (95% CI: 1.05–1.27, $p < 0.0001$, Table 3).

Combined CT and MRI scans ordered by family doctors amounted to 19,132 (0.9%) during the study period, the lowest rate of all specialties (Table 1). With regard to each physician's behavior, pediatricians ordered 4.7 ± 14.0% repeat scans, the fewest of all physicians ($p < 0.0001$, Table 2). However, there were no significant differences between pediatricians, obstetricians/gynecologists, and family physicians, in terms of repeat scan rates per physician ($p > 0.05$, Table 3).

Practice hospitals

Physicians who worked for medical centers ordered the most CT/MRI scans (including total number, repeat scan number, and repeat scan rate; $p < 0.0001$, Tables 1 and 3).

Discussion

CT and MRI offer prompt and accurate diagnosis, and have gained wide acceptance among medical professionals and patients.[10] The total number of doctors directly impacts on the rate of use of these high-end imaging modalities,[11] as well as their demographic characteristics.[10] Our study found that middle-aged (41–50 years) physicians ordered the most CT/MRI scans, contributing to 41.4% of total scans. Middle-aged physicians combined with the next-youngest group of physicians (31–40 years of age), were responsible for 80.7% of scans performed. In contrast, physicians older than 51 years alone contributed to 16.5% of total scans. It has previously been reported that younger physicians are often better educated about advanced imaging modalities and relevant indications for using them, but perhaps overly rely on advanced imaging modalities.[10] However, in our study, the youngest group was the lowest user among all ages. Several reports from Taiwan have indicated that the use of advanced images and medical expense are related to the number of doctors.[4,5,12] In our study, the numbers of physicians were lowest in the young physicians among the four age groups. This might have influenced the total use. On the other hand, for the repeat scan rate per each physician, young doctors also had the lowest amount among the groups. The youngest group was less than 31 years old in our study; most of them were

Table 3 Multivariate regression analysis of the repeat scan rate ordered by each physician (n = 16,307)

	Coefficient	95% confidence interval		p
Age (y)				
≤30	−0.29	−0.37	−0.20	<0.0001
31−40	0.08	0.02	0.13	0.0110
41−50	0.16	0.10	0.22	<0.0001
≥51	Reference	—	—	—
Sex				
Female	Reference	—	—	—
Male	0.20	0.14	0.26	<0.0001
Specialty				
Internal medicine	1.16	1.05	1.27	<0.0001
Surgeon	0.90	0.78	1.01	<0.0001
OBS/GYN	−0.05	−0.19	0.08	0.4489
Pediatrics	−0.09	−0.22	0.04	0.1759
Emergency	0.94	0.76	1.11	<0.0001
Family	Reference	—	—	—
Others	0.44	0.32	0.57	<0.0001
Nonspecialist	0.37	0.26	0.49	<0.0001
Hospital accreditation				
Medical center	Reference	—	—	—
Regional hospital	−0.34	−0.38	−0.29	<0.0001
District hospital	−0.79	−0.85	−0.73	<0.0001

OBS/GYN = obstetrics/gynecology.

residents in training without a specialty. This might be the reason that their use of scans was the lowest among all age groups. The physicians aged 31−50 years were specialists, and their education on the use of CT or MRI scans and awareness of the need for both the scans, when the situation arises, might be the reasons why they were the most frequent users. Male physicians used more CT and MRI than female physicians regarding both total numbers and repeat scans. This might reflect the concentration of male and female physicians in certain specialties. However, it might also be due to sex characteristics; studies have indicated that male physicians are more likely to perform interventions, such as cardiac catheterization[13] or cesarean section.[14] To the best of our knowledge, this is the first study showing that male physicians perform more CT and MRI examinations for both total numbers and in repeat scans.

Physicians working in medical centers used the most CT and MRI scans of all the three categories (total number, number of repeat scans, and repeat scan rates). Katz et al[15] showed that doctors who trained in prestigious hospitals are more likely to be considered the "best doctors". However, different use of high-cost imaging among physicians in medical centers compared with that of smaller hospitals has not been previously addressed. Physicians in medical centers might prefer high-cost imaging, such as CT or MRI, because of their training, research requirements, or for teaching purposes. The heavy use of CT/MRI scans in such centers might also reflect a patient population with more complex medical problems that require more high-cost imaging studies.

Each medical specialty varies considerably from one another in their use of CT and MRI, with internal medicine being the heaviest users. Lee et al[1] observed that for oncology treatment, chest nodules were the most common indication for repeat chest and abdominal CT and stroke, intracranial bleeding or trauma, was the most common indication for repeated head CT. Kung et al[16] reported that neoplasm, diseases of the circulatory system, and congenital malformations had significantly higher CT use. These findings might explain why internal medicine physicians use the most CT and MRI, and surgeons used the second most CT and MRI in our study. Katz et al[17] reported that the total number of radiological examinations is higher for patients who need an operation. CT or MRI is also needed for a wide range of diagnoses, conditions, preoperative evaluations and postoperative follow-ups. This may be the other reason why surgeons ranked second in CT/MRI use. Medico-legal issues may also have a significant effect on doctors' behavior. Many doctors practice defensive medicine that involves unwarranted tests, imaging, and consultation with the aim of preempting possible lawsuits.[18] Some authors have expressed doubts about the effectiveness of this approach.[11,19,20] However, this might be one of the reasons that doctors in the emergency room ranked first among specialties in total number of scans per physician, and in repeat scans per doctor. Other reasons may be the relative lack of emergency doctors in Taiwan (n = 316), or the complex conditions of patients in the emergency room.

Family doctors, obstetricians/gynecologists, and pediatricians ranked last among specialists in CT/MRI use. Previous researchers have investigated family doctors' behavior regarding seemingly excessive use of blood tests.[21] The education of family physicians addressed the use of CT or MRI scans.[22] However, from the results of our study, it is apparent that family doctors do not contribute to the increasing use of expensive medical imaging modalities, most likely because they refer their patients to other specialties when the patients have complicated diseases.

For better use of limited medical resources, NHI restricted the repeat use of CT and MRI within 90 days. This reduced the use to approximately 0.96% for CT and 1.01% for MRI.[9] In the United States, some health management organizations also audit the use of CT and MRI scans.[10] A restriction might be necessary for reducing the "supplier-induced demand". From our study, we recommend setting a different monitoring standard for different accreditation levels of hospitals and different specialties. The threshold for the medical centers, the internal medicine physician, and the surgeon should be higher than that for the others. Future studies on repeated use of CT/MRI among different subspecialties of internal medicine and surgery, or different diseases may offer a more detailed recommendation of restriction, and therefore provide more policy implications.

Summary statement

In conclusion, our population-based study shows that use of CT/MRI repeat scans is related to physicians' age, sex,

specialty, and practice hospital level. We recommended setting a different monitoring standard of repeated use of CT/MRI for different accreditation levels of hospitals and different specialties.

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